(2)

NATIONAL COMMUNICATIONS SYSTEM

AD-A173 520

NCS EMP MITIGATION PROGRAM:

AERIAL TI SYSTEM EMP TEST PLAN

AUGUST 1986

OFFICE OF THE MANAGER
NATIONAL COMMUNICATIONS SYSTEM
WASHINGTON, D.C. 20305

DCA-100-82-C-0034

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION / AVAILABILITY OF REPORT
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION / 6b. OFFICE SYMBOL *(If applicable)*	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS *(City, State, and ZIP Code)*	7b. ADDRESS *(City, State, and ZIP Code)*
8a. NAME OF FUNDING / SPONSORING ORGANIZATION National Communications System / 8b. OFFICE SYMBOL *(If applicable)* NCS-TS	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER DCA100-82-C-0034
8c. ADDRESS *(City, State, and ZIP Code)* Technology & Standards Washington, D.C. 20305-2010	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE *(Include Security Classification)*
NCS EMP Mitigation Program: Aerial T1 System EMP Test Plan

12. PERSONAL AUTHOR(S)

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT *(Year, Month, Day)*	15. PAGE COUNT
Final	FROM ______ TO ______	August 1986	30

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*
FIELD	GROUP	SUB-GROUP	EMP High-Altitude EMP (HEMP) National Security & Emergency Preparedness (NSEP)

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*
This program mitigates the damaging effects of nuclear weapons on regional and national telecommunications capabilities. To meet this objective, the OMNCS has sponsored efforts to create a network level model to assess the effects of High-Altitude EMP (HEMP). In addition, the OMNCS has sponsored efforts to collect the level HEMP effects to data required to support the network-level model. The products of this model will assist the NCS in identifying potential vulnerabilities of national telecommunications capabilities to HEMP and to support National Security & Emergency Preparedness (NSEP) initiatives.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified	
22a. NAME OF RESPONSIBLE INDIVIDUAL Dennis Bodson	22b. TELEPHONE *(Include Area Code)* 202-692-2124	22c. OFFICE SYMBOL NCS-TS

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

NATIONAL COMMUNICATIONS SYSTEM

NCS EMP MITIGATION PROGRAM:

AERIAL TI SYSTEM
EMP TEST PLAN

AUGUST 1986

OFFICE OF THE MANAGER
NATIONAL COMMUNICATIONS SYSTEM
WASHINGTON, D.C. 20305

DCA-100-82-C-0034

TABLE OF CONTENTS

L I S T O F E X H I B I T S

1.0 INTRODUCTION

The Office of the Manager, National Communications System (OMNCS) has undertaken the Electromagnetic Pulse (EMP) Mitigation program to support the survivability objectives addressed by National Security Decision Directive 97 (NSDD-97) and Executive Order 12472. The objective of this program is to mitigate the damaging effects of nuclear weapons on regional and national telecommunications capabilities. To meet this objective, the OMNCS has sponsored efforts to create a network-level model to assess the effects of High-Altitude EMP (HEMP). In addition, the OMNCS has sponsored various efforts to collect the level HEMP effects data required to support the network-level model. The products of this model will assist the NCS in identifying potential vulnerabilities of national telecommunications capabilities to HEMP and to support National Security and Emergency Preparedness (NSEP) initiatives.

In support of the OMNCS efforts to obtain appropriate equipment-level HEMP effects data required for the network-level model, the OMNCS is assessing the survivability of the aerial T1 carrier system. The survivability of buried T1 carrier system against the effects of HEMP was the subject of extensive analysis and testing efforts under the T1/FT3C Nuclear Weapons Effects project, which was funded by the NCS (Reference 1). As a result of these efforts, a wealth of information exists, some of which is applicable to the aerial T1 equipment. The approach to the aerial T1 assessment is to use as much of the existing data as possible and to augment that data, where appropriate, through analysis and simulation testing in order to identify potential vulnerabilities to HEMP.

This document is a plan for the simulation testing portion of the aerial T1 carrier system assessment. This test plan identifies the following: test objectives, data that are to be collected, the logistic support required to accomplish the test, and pre-test analysis.

2.0 SCOPE OF TESTING

Many equipment configurations exist for T1 carrier transmission systems. For the purpose of this program, the selected test configurations are representative of those found in recent aerial installations.

To avoid the added time and expense of conducting an operational test program, this test will be conducted as a coupling study for representative T1 aerial cable configurations. The coupling studies will be used in conjunction with the results of related test programs (Reference 1, 2, 3) to assess the survivability of lightning protected and unprotected systems against early time HEMP.

In order to assess the system survivability, the measured cable transients and cable properties will be used to establish the threat signal levels that would be seen by aerial T1 system repeaters, channel banks, and Transient Protection Devices (TPDs). Switches will not be used in this test since other test programs are addressing their survivability. Repeaters and TPDs were tested during the Buried T1 Carrier Tests. Tests are being conducted on the D4 channel bank and the 5ESS switch, while other tests are being planned for the DMS-100/200 switch .

3.0 TEST OBJECTIVES

The purpose of the Aerial T1 Cable tests is to develop an empirical data base describing the transients induced on typical T1 cables in the HEMP threat environment.* This data base will support the survivability assessment of the aerial T1 Transmission System to HEMP.

The general objective of this series of tests will be to measure the coupling of simulated HEMP to long aerial cables. The specific objectives, for a representative cable configuration, are as follows:

- To measure bulk, binder, and signal wire induced transients for a representative aerial T1 cable.
- To measure the propagation characteristics (impedance, propagation constant) of the cable(s) above a finite ground plane.
- To measure the coupling and propagation characteristics of cables with typical splice case configurations installed.

By completing these objectives, a data base consisting of transfer functions can be obtained to evaluate the induced stresses at line repeaters, TPDs, and D4 channel banks. These results can be used to help assess system survivability when they are integrated with the results of D4 channel bank testing, switch testing, and the data obtained on repeaters and TPDs in the Buried T1 Cable tests.

---

*That is, the 50 kV/meter double exponential threat (DBEX) discussed in Reference 4.

4.0 TEST FACILITIES AND EQUIPMENT

In order to carry out the test program on a representative aerial T1 carrier transmission system, the facilities at Harry Diamond Laboratories (HDL) Woodbridge Research Facility will be used for cable driving and field illumination studies. The test equipment and T1 carrier hardware is described in this section.

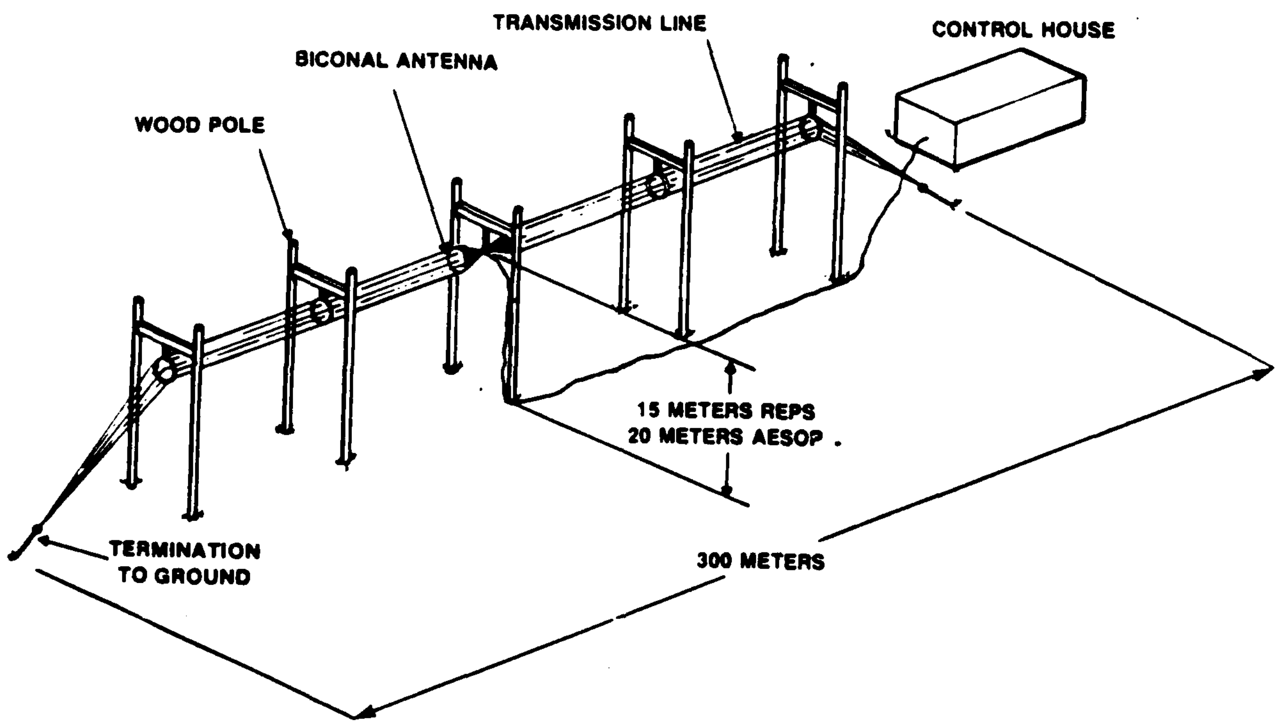
4.1 TEST EQUIPMENT

A wide range of facilities at HDL will be used. The cable testing laboratory at HDL will measure common-mode propagation properties of T1 carrier cables. HDL has two radiating field pulse generators that can be used extensively to study the electromagnetic coupling to the cables.

The radiating pulser to be used is called the Army EMP Simulator Operation (AESOP). The AESOP is a 300-meter-long, 20-meter-high (approximately 984-feet by 65-feet), radiating dipole antenna. The AESOP generator drives a 7-million-volt pulse through a biconal antenna and down a horizontal transmission line composed of a cylindrical array of wires. The transmission line is terminated to ground at both ends (see Exhibit 1). The biconal antenna forms the early-time shape of the pulse, while the transmission line forms the late-time portion of this pulse. The AESOP produces, at most, a 50-kV/meter horizontal incident field at 50 meters and a 25-kV/meter incident field at 100 meters (300 feet). Coupling experiments will be performed at the latter field level. This field is largely horizontally polarized. The near-induction-zone fields under the simulator reach magnitudes on the order of 100 kV/meter.

The tests to be conducted at HDL will use the cable drive laboratory to do Time Domain Reflectometry (TDR) and obtain signal wire-to-sheath transfer functions. The System for Monitoring and Recording Transients Intermentation Van (smart IVAN) will also be used to record data and provide quick look plots as well as on-site data processing for the field studies.

Exhibit 1. AESOP Simulator



4.2 T1 CARRIER HARDWARE

A typical T1 carrier system might be arranged as shown in Exhibit 2. The central office equiment is shown in the boxes and is interconnected by the outside plant equipment, consisting of T1 carrier lines. The remote customer end is served by the channel bank, protection switch, and office repeater combination as shown to the left. The optional protection switch changes to a spare T1 carrier line in the event of a signal failure at the receiving end. At an intermediate central office (e.g., in the lower box) the entire digroup is demultiplexed so that some voice-frequency channels may be directed to a customer while the remaining voice-frequency channels are multiplexed onto the outgoing T1 carrier. The third type of office configuration shown in Exhibit 2 is used only for supplying power to the T1 carrier line; there is no voice-frequency application.

The outside plant equipments for this system are repeaters and splice cases. The 818/819-type repeater case is designed to house 25 T1 carrier repeaters, a fault locate filter, a pressure contactor, and other ancillary equipment see Figure 3. The case is molded from a fiber glass-reinforced plastic (sheet molding compound) and designed to be either pole-mounted or installed in a manhole. The case has been in manufacture since 1978 and is the primary case now being deployed for the T1 carrier system.

Three types of splice cases are employed for T1 carrier routes. Cast-iron splice cases, such as the 30D type; plastic splice cases, such as the 2D2 type; and pedestal cable closures, such as the PC-12.

The cast-iron splice case is designed to be used aerially, buried, or in manholes. Cable-sheath continuity at the splice case is achieved through the cast-iron halves of the splice case itself and with a copper braid (see Exhibit 3).

The plastic splice case is also designed to be used aerially, buried, or in manholes. Cable-sheath continuity at the splice is achieved by bridging across the splice with a copper braid (see Exhibit 4). This arrangement provides a good current path across the splice.

The pedestal-type cable closure is designed for use with buried or aerial cable where the splice closure can be mounted at ground level (see Exhibit 5). Continuity of the cable sheath at the splice is achieved with copper bonding cables that provide a good DC path across the splice.

Exhibit 2. T1 Carrier System Configuration

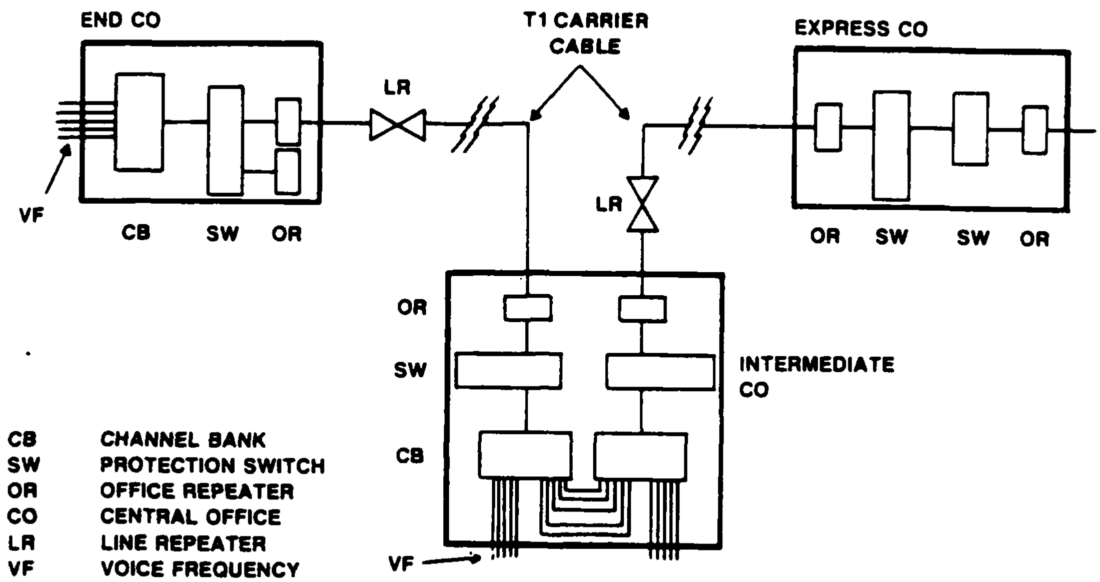


Exhibit 3. Cast-Iron Splice Case

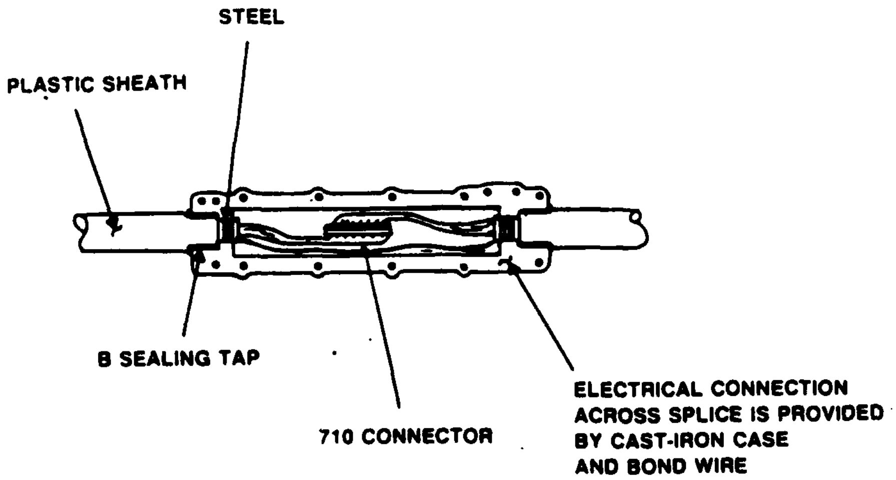


Exhibit 4. Plastic Splice Case (2 type)

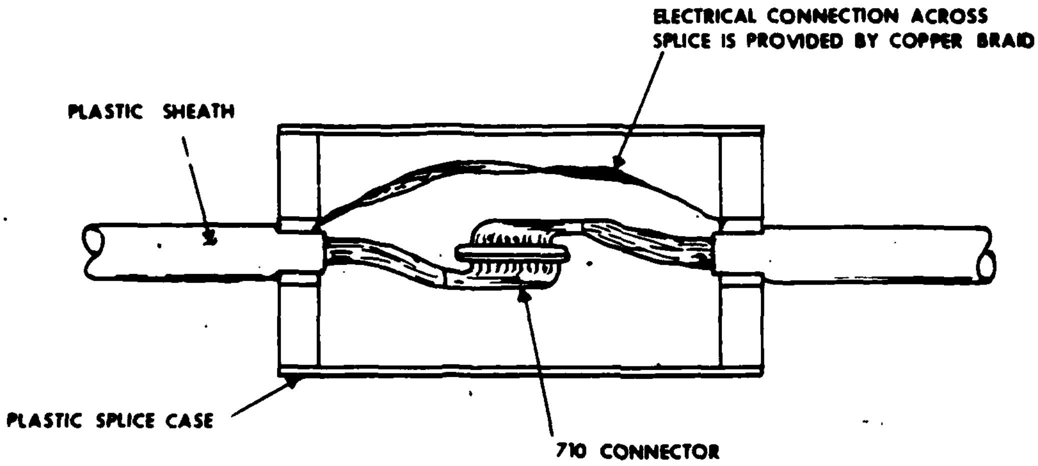
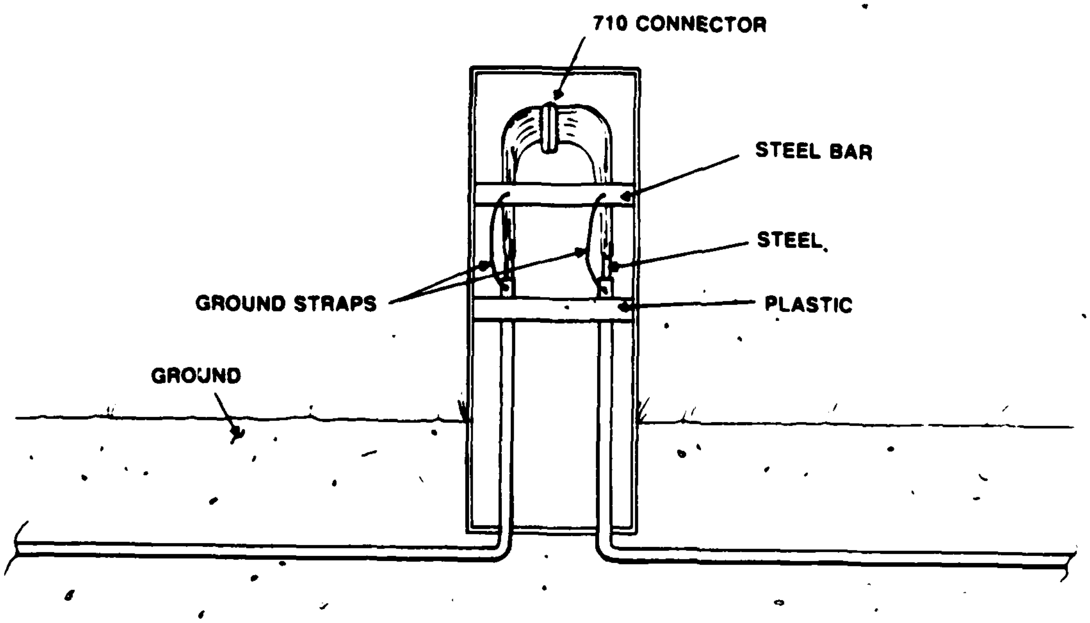


Exhibit 5. PC-12 Cable Enclosure



5.0 PROCEDURES

The objectives of the T1 Aerial Cable Test will be met by several complementary activities. These activities include laboratory cable driving studies, field illumination studies, and analytical studies. This section discusses the activities and test configuration in detail, and as present a summary test matrix for meeting the objectives discussed in section 3.0.

5.1 CABLE DRIVING STUDIES

A series of laboratory surge tests will determine the transmission characteristics of a representative sample of multipaired cables and splice cases. These transmission-line tests include measuring the transfer impedance, Z_t, transfer admittance, Y_T, the common-mode characteristic impedance, Z_o, and the propagation constant, γ, as functions of frequency. Exhibit 6 illustrates the definition of Z_T. A knowledge of Z_T, Y_T, Z_o, and γ will permit a calculation of the transient response of this cable.

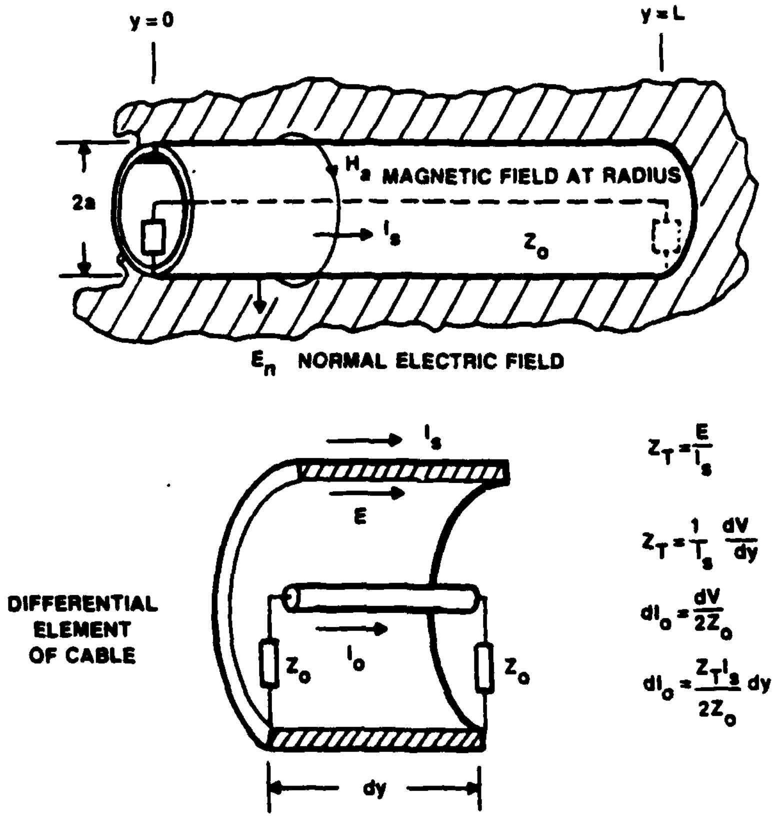
As a cross check, the transmission line measurements also will include data taken in the time domain using time-domain-reflectometry (TDR).

Exhibit 7 illustrates the structure of KHAG 106, a specifically designed aerial T1 cable. The core of the cable is shielded primarily by the aluminum sheath. T1 carrier cables generally have 100 or more twisted wire pairs arranged in groups of 25 pairs. Each group is called a binder group. These binder groups are surrounded by various metal shields. Each binder group twists at a uniform rate with respect to the others; however, the binder groups do not braid. The pairs within a binder group twist with respect to each other. The KHAG 106 cable has four binder groups.

5.1.1 Cable Sheath

The transfer function, Z_T, of a representative 3 meter length of T1 transmission cable, the KHAG 106, will be measured. The measurements will help determine the shielding effectiveness of the aluminum outer sheath.

Exhibit 6. Definition of Cable Transfer Function



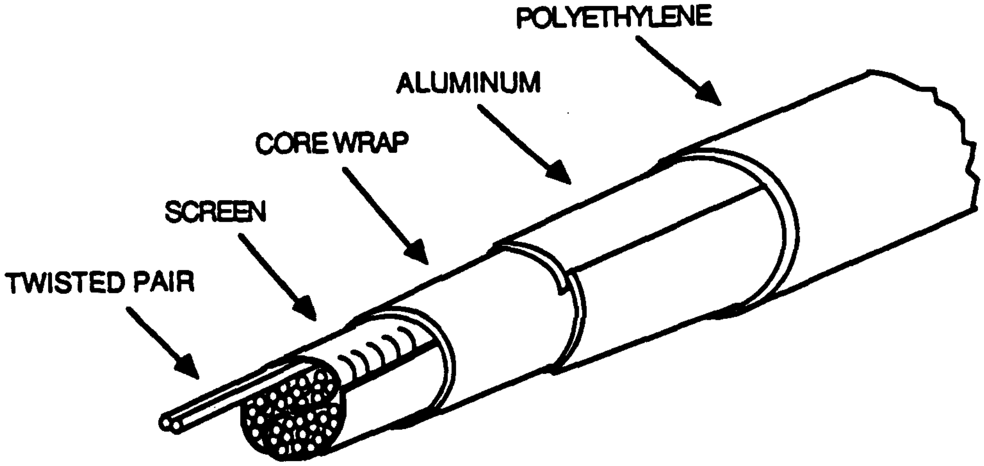
TOTAL CURRENT I_{LOAD} AT THE END OF THE CABLE IS

GREEN'S FUNCTION

$$I_{LOAD}(\omega, y = L) \quad \frac{Z_T(\omega)}{2Z_o} \int_o^L dy' G_H(y, y', \omega)\, I_S(y', \omega)$$

$$\int_o^L dy' G_H(y, y', \omega)\, I_S(y', \omega)$$

Exhibit 7. Structure of KHAG 106 Cable



5.1.2 Z_T Measurements

Z_T from the cable sheath to conductors within the cable core will be measured as a function of frequency over the relevant EMP range. These measurements, to be conducted at HDL, will determine the following quantities:

- Z_T from the sheath to a binder group within the cable
- Z_T from the sheath to a single conductor within a binder group
- Differential voltages between binder groups and between single conductors within binder groups.

5.1.3 Time-Domain Reflectometry (TDR) Experiments

TDR experiments for the KHAG 106 sample, will measure,

- The characteristic common-mode impedance
- The common-mode propagation constant.

5.2 ILLUMINATION STUDIES

Field experiments with AESOP will determine the coupling of the horizontal simulated EMP components to the cables and the line splice case structures. Coupling to the core conductors in these long, multipaired cables of large cross section is not well understood. It is difficult to make predictions with high confidence about induced transients to the core conductors and, thus, to the terminating line repeaters. For those reasons, field experiments will be taken to determine coupling on the aerial cable configuration.

Since a high-altitude EMP extends over an area of thousands of square miles, it would uniformly excite the 1 mile (1.6 kilometers) of cable between T1 repeater sites. No existing simulation facility can produce uniform fields over such dimensions. However, as shown in Appendix A, shorter lengths of aerial cable can accurately produce the early-time response of the cable sheath open-circuit voltage to a simulated EMP. Cable lengths of several hundred feet are sufficient (shown in Appendix A). Extrapolations for optimal coupling orientations will be made to estimate the optimal coupled transients.

To study the coupling of a horizontally polarized EMP, two mirror image lengths of cable will be suspended along a circular arc of radius 100 meters about the center of the AESOP (see Exhibit 8). The cable section A has splice case sites and a steel support messenger strand that is bonded to the guy wires and splice cases. This geometry coincides approximately with contours of equal arrival time and field strength of the pulse; this simulates plane-wave incidence along several hundred feet of cable. A calculated representation of the sheath-current waveform is presented in Appendix A.

There is another aspect for which the experimental arrangement differs from the normal outside plant configuration. In commercial installations, cable is suspended at about 6 to 7 meters, but for the field tests the cables will be suspended at 5 meters.

The primary function of cable A and the splice case site on the simulator centerline is to determine the characteristics of a typical aerial configuration with the appropriate support, grounding, and bonding practices installed.

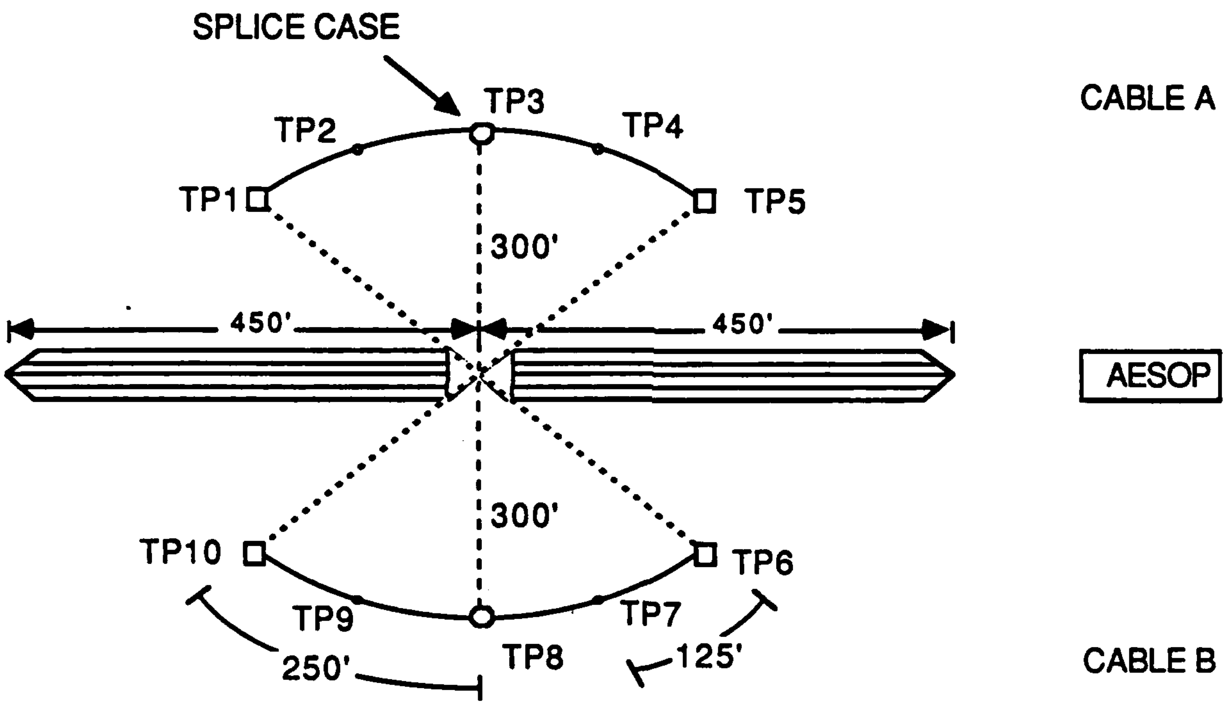
Measurements of bulk current and individual conductor current taken on cable A will be compared with corresponding measurements made on cable B. The effects of the support, bonding, and grounding can be compared using cable B, where the cable configuration does not have the bonding and grounding practices installed.

5.2.1 Field Coupling Studies

Exhibit 8 also shows the test point locations at the AESOP site. Two sections of 168 meters long and 5 meters high will be arranged in a circular arc at a distance of 100 meters from the center of AESOP. These cables were referred to as cable A and cable B, above.

Test points 1, 5, 6, and 10 are the end points of cable sections A and B and will be grounded while bulk current measurements are made at test points 2, 3, 4, 7, 8, and 9. The type of termination that yields the best ground will be determined experimentally.

Exhibit 8. Cable Test Configuration for HDL Coupling Studies



Individual wire measurements will be obtained by inserting a repeater housing (no repeater) at test points 2 and 9. Measurements will be taken of the open-circuit voltage (V_{OC}) and short-circuit (I_{SC}) current as well as the differential voltage (V_{DIF}) on the input and output leads in the antechamber to a repeater case.

The cable (section A) core response will be measured at TP1, with TP5 grounded, as follows:

- I_{SC} and V_{OC} to earth ground for the cable shield
- I_{SC} and V_{OC} for each distinct binder group to the cable shield
- I_{SC} and V_{OC} for a single conductor in each binder group to the cable shield
- The differential voltage between distinct binder groups.

Time Domain Reflectometry (TDR) experiments will be performed on the cable sections. The procedure will be to inject a signal at TP5 to measure the common-mode transmission parameters (i.e., characteristic impedance and propagation constant). The results of these measurements can be compared to the 3 meter cable in the laboratory studies. For comparison, similar measurements (TDR, bulk, and individual wire) will also be made on cable section B.

5.2.2 Splice Case Studies

For cable section B at TP8, typical aerial T1 splice cases can be inserted in the latter stages of the coupling study after measurements are performed with no splice in place. The measurements with the splice case(s) in place can help determine the extent of the current induced in signal leads by the sheath current at the splice. Because the cable terminates abruptly at the splice case, radiation from the sheath is expected because of the large impedence change. This radiation will partially manifest itself as transients on the signal wires.

The types of measurements at the splice case(s) will include:

- Bulk current on each side of the cable
- I_{SC} and V_{OC} inside the splice case on the core, binder group, and signal wire.

5.2.3 Current Sharing Studies

In most cases, aerial T1 cables will have additional cables suspended in parallel over a portion of a given route. Exhibit 9 shows a typical multicable configuration that can be present in a system. Additional illumination studies for this configuration will help to characterize the effects of mutual current sharing on the transmission systems.

In this experiment, the bulk current will be measured on up to three cables. These measurements will be compared with the measurements on the bulk current for single cables and compared with the results of the bulk current for the single cable. Though the sheath current may be reduced through mutual induction interactions, the total current may actually increase over that of one cable at a termination.

5.3 TEST POINT SUMMARY

Exhibit 10 shows a summary of measurements to be made at the test points. Each of the measurments will contribute to satisfying one or more of the objectives outlined in Section 3.

5.4 DATA COLLECTION

All data will be taken with fiber-optic instrumentation and the IVAN. For measurements at the ends of cables, HDL will provide a well-shielded breakout box so that the individual cable and internal bulk currents can be measured.

Individual data records (paper plots and floppy disks) are provided for each shot. These data will be corrected for all instrumentation calibration. A B-dot monitor will be used to record the relative field strength for each simulator pulse. Measurements of the magnetic and electric fields close to test points 1 through 10 will also be made prior to field testing of the system.

Exhibit 9. Multiple Cable Configuration

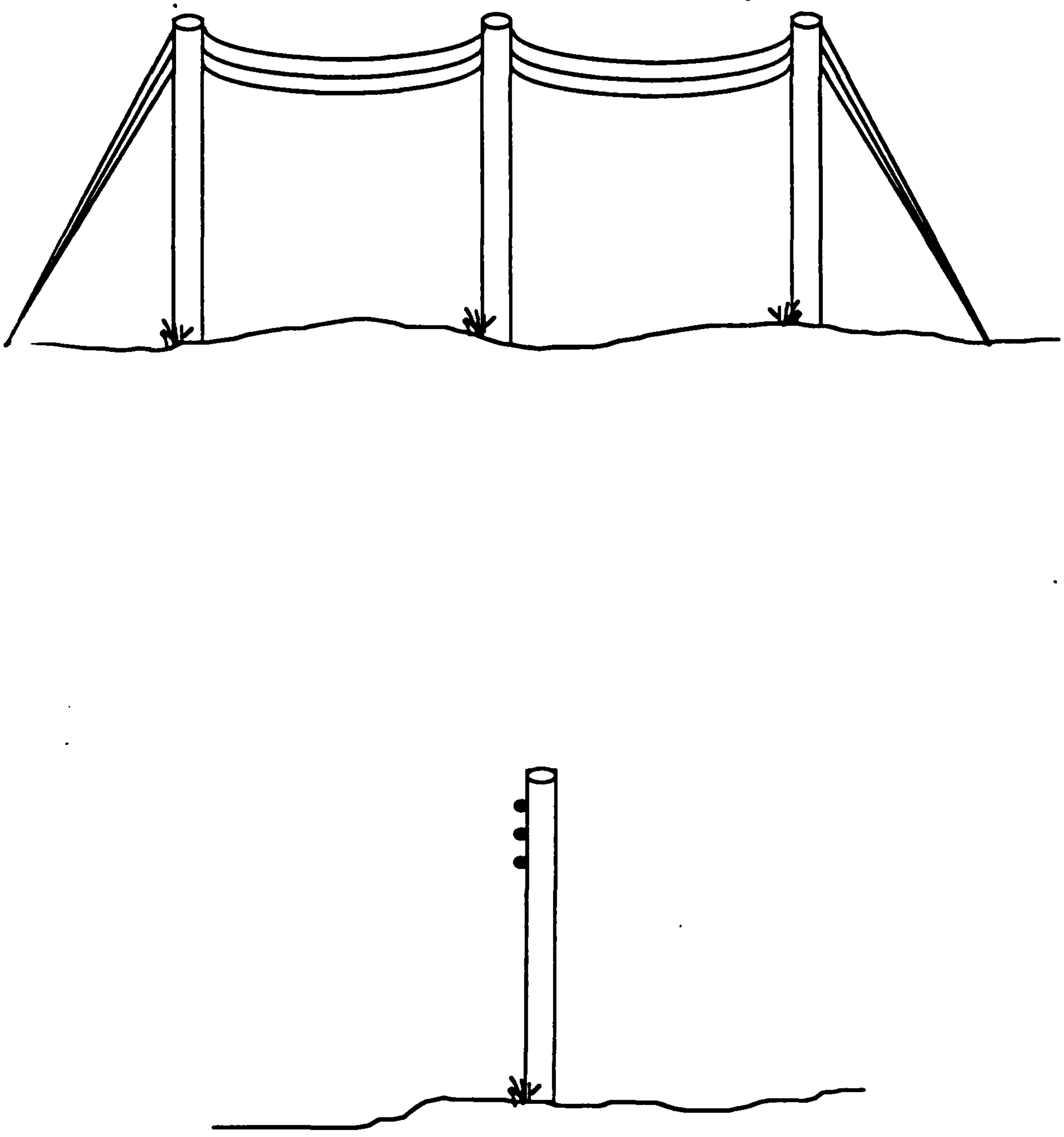


Exhibit 10. Test Point Summary

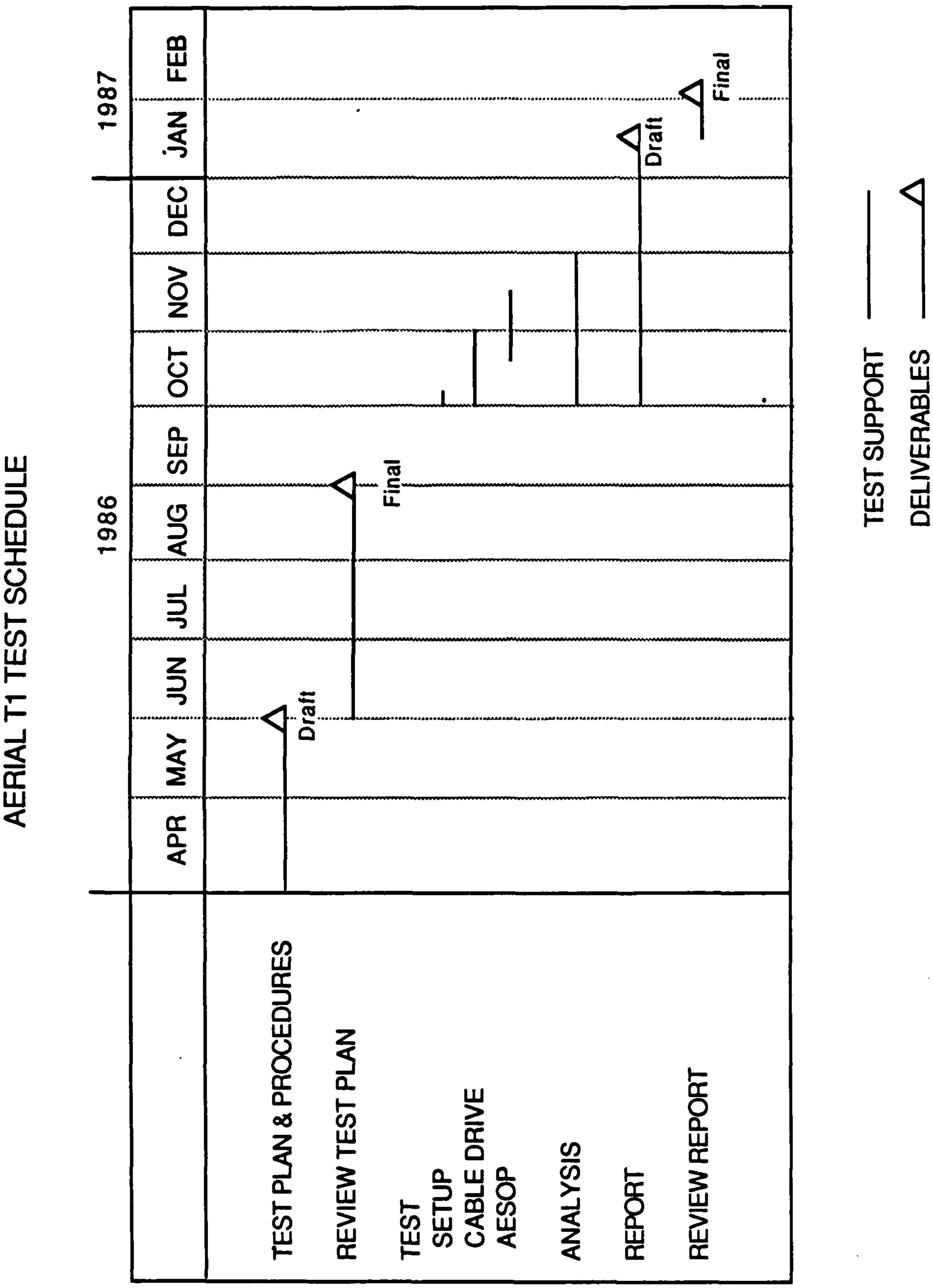
TEST POINT SUMMARY

CABLE	TEST POINT	ACTIVITY
A	TP1	TDR mesurements (input)
A	TP2	Signal wire measurements
A	TP3	Splice case insert - bulk & signal current measurements
A	TP4	Bulk current measurements
A	TP5	TDR measurements - bulk current measurements
B	TP6	TDR measurements (input)
B	TP7	Signal wire measurements
B	TP8	Splice case insert - bulk & signal current measurements
B	TP9	Bulk current measurements
B	TP10	TDR measurements - bulk current measurements

6.0 SCHEDULE

Exhibit 12 is a test schedule that will require six weeks of testing at HDL. The start of this test period is October 1.

Exhibit 11. Test Schedule



7.0 REFERENCES

1. Nuclear Weapons Effects. T1 EMP/MND Hardness Assessment and Design, Final Report, Volume 1-17. November 29, 1985, AT&T Bell Laboratories.

2. EMP Assessment of D4 Channel Bank, in progress.

3. EMP Assessment of SESS Switch, Final Report, in preparation.

4. EMP Engineering and Design Principles. Bell Telephone Laboratories, 1975.

APPENDIX A

PRETEST ANALYSIS

APPENDIX A

PRETEST ANALYSIS

A widely used characterization for the early-time HEMP threat waveform is the double exponential (DBEX) expression:

$$E(t)=E_0\,(e^{-\beta t} - e^{-\alpha t})$$

where

E_0 = peak field amplitude =52.5 kV/m

$\alpha = 4.76\times10^{8}$ sec $^{-1}$

$\beta = 4.00\times10^{6}$ sec^{-1}

Exhibit A-1 displays this HEMP waveform which is the waveform at 50 meters from the AESOP HEMP simulator. Also shown is the waveform at 100 meters from the pulser where the test cable will be located.

To estimate the coupled transient on the cable sheath in this test, the Electromagnetic Pulse Effects on Cables (EPEC) program was used. This program uses a DBEX pulse to calculate the voltage or current transients on lossy aerial or underground cables. The geometry of the test configuration is shown in Exhibit A-2. From this geometry, the coupling of the simulated threat can be calculated for horizontal polarization (the primary polarization of the AESOP simulator).

The estimated response of the cable to the simulated threat field at 100 meters is shown in Exhibit A-3. the EPEC program assumes a simi-infinite length of cable. For practical purposes, this assumption is valid for finite length cables if the length of the cable used in the test is sufficient enough to couple at least twice the pulse width of the transient. The length of cable required by this criteria is 500 feet.

Exhibit A-1. Simulated HEMP Threat Waveform

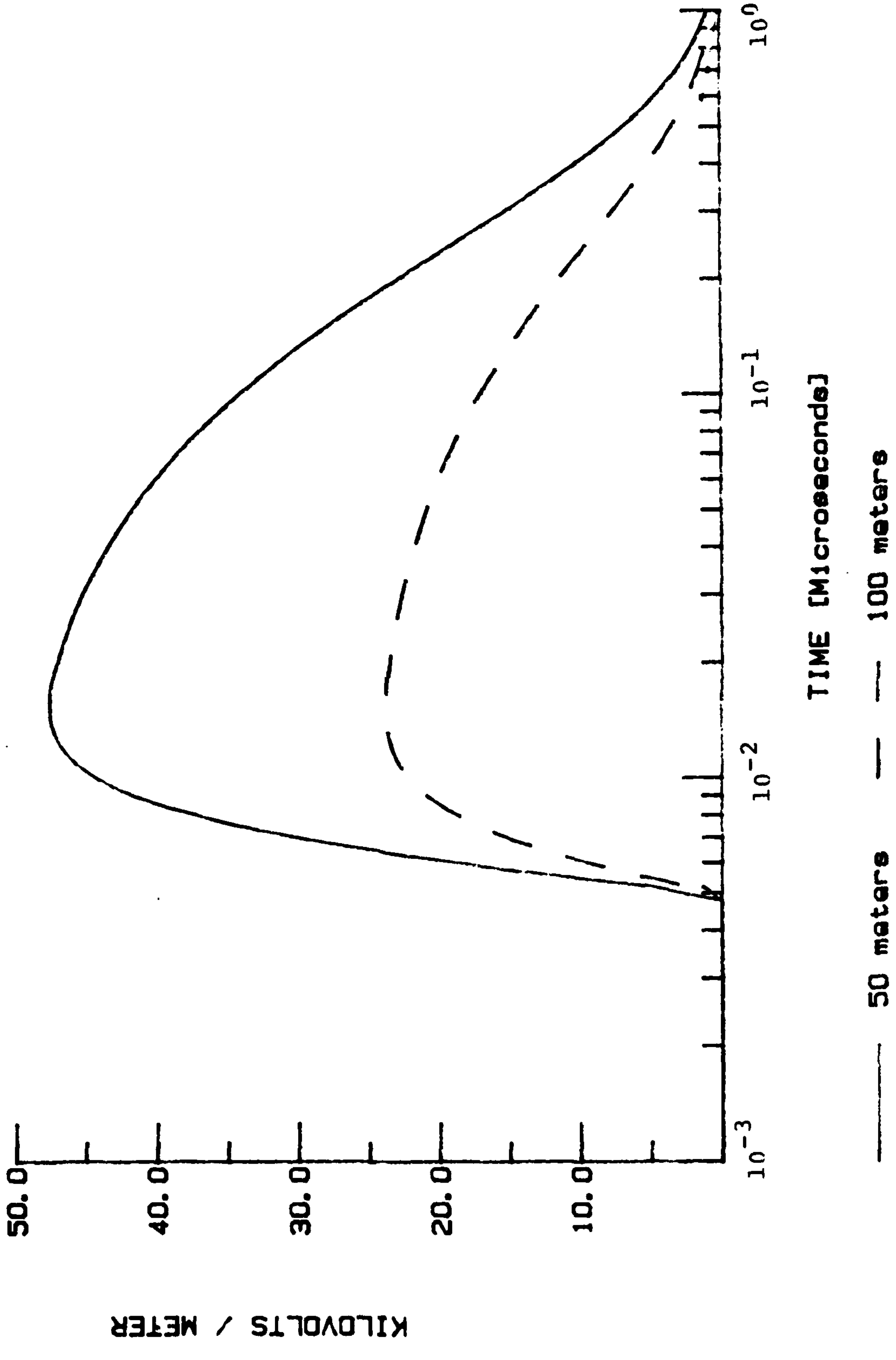


Exhibit A-2. Cable Test Geometry

D	E	ψ_o
50 M	50 Kv/M	16.7
100 M	25 Kv/M	8.5

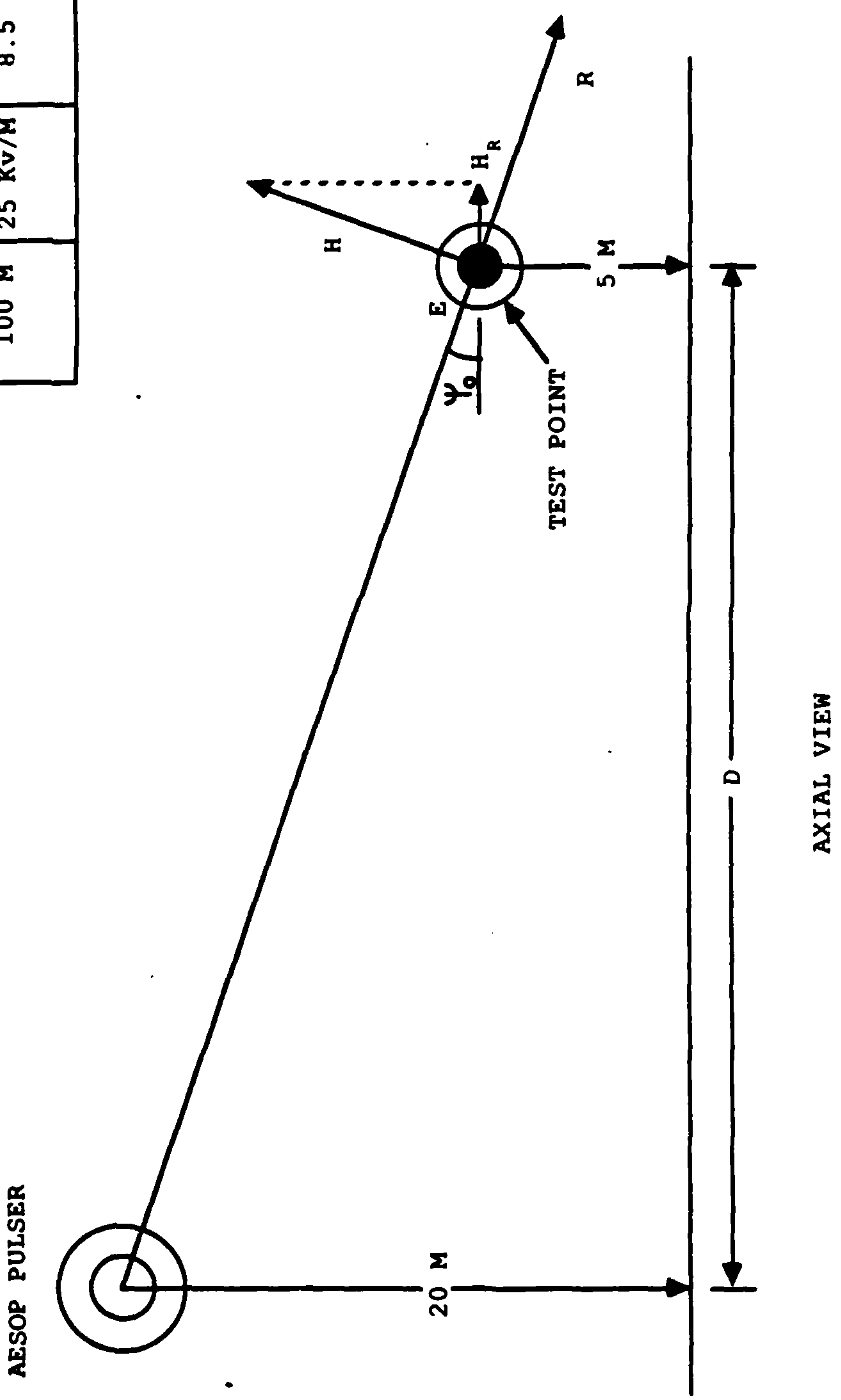


Exhibit A-3. Cable Response Waveform